Amendments to the Specification:

Please amend the paragraph beginning on page 3, line 21 as follows:

In yet another aspect, the invention provides for a method for measuring the overlay alignment of at least two layers of a semiconductor device using a wavefront sensing tool. The method includes generating a reference signal by observing a flat reference surface with the wavefront sensing tool and storing the resulting signal, aligning at least a portion of the semiconductor wafer containing a first and second alignment mark with the wavefront sensing tool, and illuminating the portion of the wafer and detecting a wavefront of light reflected from the portion of the wafer and from the first and second alignment marks. The method further includes magnifying the reflected wavefront of light, generating [[an]] a wavefront slope signal by observing the magnified reflected wavefront of light with the wavefront sensing tool, determining the location of the first and second alignment marks [[be]] by comparing the wavefront slope signal with the reference signal, and calculating a distance between the first and second alignment marks based upon the results of the step of determining the location of the first and second alignment marks.

Please amend the paragraph beginning on page 6, line 1 as follows:

Figure Figures 4c and 4d illustrate preferred alignment features and the wavefront distortion caused by them, respectively;

Please amend the section title on page 6, line 15 as follows:

DETAILED DESCRIPTION OF PREFERRED ~~EMBOIDMENTS~~ <u>EMBODIMENTS</u>

Please amend the paragraph beginning on page 7, line 1 as follows:

Figure 1A illustrates a top view of exemplary alignment features at different levels (layers) of a semiconductor device. The alignment mark 10 includes a first alignment feature 12 and a second alignment feature 14. The alignment features 14 are produced by conventional methods of photolithography and are formed of material in an underlying layer, such <u>as</u> silicon, polysilicon, oxide, nitride, metal layer, or other known semiconductor layer. Alignment marks 12 are formed in a top layer of photoresist material. For illustrative purposes, the alignment mark 10 is shown as a conventional box -in-box or frame-in-frame configuration. Detection and measurement of other alignment geometries is within the scope of the present invention as well.

Please amend the paragraph beginning on page 8, line 4 as follows:

Figure 2 illustrates a first preferred embodiment system 1 for detecting and measuring alignment marks 12, 14 located on a wafer 5. The system includes an illumination source 2 that illuminates wafer 5 (or portions thereof, including the portions containing alignment features 12, 14) with a light beam 4. The wafer 5 is preferably mounted on a stage 7 that allows for relative movement between the wafer 5 and a wavefront sensing tool 8 in order to scan across the wafer surface. The stage 7 operates under the control of motors and control logic 9. In other embodiments, wafer 5 may be held stationary and wavefront sensing tool 8 is operated to move relative to the wafer in

order to perform the scan. In still other embodiments, light from illumination source 2 can be directed through the use of alignment mirrors and focusing optics to scan across different regions of a stationary wafer. Illumination source 2 can be any appropriate light source of strength. Typical illumination sources currently used in semiconductor manufacturing include a number of incoherent (incandescent and discharge lamps) and coherent (lasers) sources in the 157 nm to 800 nm wavelength range – although the scope of this invention is not limited to any particular type of illumination source. The light beam reflects off of the surface 13 of the wafer and alignment features 12, 14 and impinges upon alignment mirror 6, where the light beam is aligned to the input of wavefront sensing tool 8. One skilled in the art will recognize that various optical components of the system 1, such as focusing lenses, additional alignment mirrors, light shields, and the like, are part of the preferred embodiments, but are not included for clarity of the drawings because they are not necessary to an understanding of the present invention. Likewise, other features that may be included in the preferred embodiment system but not necessary to understanding the invention – such as a wafer mounting assembly – are omitted from the drawings for clarity, although one skilled in the art will readily recognize their applicability. As will be described in greater detail below, wavefront sensing tool 8 receives the light beam that has been reflected off of, and hence distorted by, surface 13 and alignment features 12 and 14. By detecting the distortion imparted onto the light beam by the features 12 and 14, wavefront sensing tool 8 is able to measure the relative placement (i.e. the displacement of and hence the alignment between) alignment features 12, 14.

Please amend the paragraph beginning on page 9, line 13 as follows:

Figure 3 illustrates wavefront sensing tool 8 in greater detail. In the preferred embodiments, wavefront sensing tool 8 comprises a Shack-Hartmann detector. The principles and operation of Shack-Hartman sensors are well known in the art. Reference is made to U.S. Patent No. 6,184,974 for additional information relating to the Shack-Hartmann sensor, which patent is incorporated herein by reference. Briefly, incoming light beam 4 impinges upon the wavefront sensing tool 8 after reflecting off of the surface and surface features (including alignment features 12, 14) to be measured. In the preferred embodiments, the light beam 4 passes through optics, such as telescopic lens 19. Light beam 4 is magnified by lens 19 as is shown schematically in the figure. Lens 19 provides greater resolution and sensitivity of the tool 8.

Please amend the paragraph beginning on page 10, line 1 as follows:

The magnified light beam 4 passes through lens 19 and impinges upon lenslet array 20. Array 20 operates to split light beam 4 into a series of light rays 21 that are spot focused on sensor array 22. In other words, sensor array 22 is in the focal plane of lenslet array 20 and hence the light rays 21 reach sensor array 22 as an array of tightly focused spots of light 23. In the preferred embodiments, sensor array 22 is a charge coupled device (CCD) array, although other alternative arrays such as CMOS photosensors, photodiodes, photographic film, and the like could be employed. Likewise, lenslet array 20 could alternatively be replaced with an aperture array or the like. The resolution of a typical lenslet array 20 is about 100 to 200 microns. In other words, the array 20 can only resolve vertical deviations between features that are spaced no less than 100 to 200

microns ~~spaced~~ apart. ~~Lens19~~ Lens 19 allows for greater sensitivity [[be]] by magnifying

a portion of the surface being analyzed – thus the lenslet array 20 is provided a magnified

image upon which to resolve.

Please amend the paragraph beginning on page 10, line 15 as follows:

In operation, a reference surface such as a (near) perfectly flat surface is scanned

by wavefront sensing tool 8 and the location of the spots 23 measured. This provides a

reference measurement. Next, the surface to be measured for alignment is scanned and

the location of the spots 23 once again measured. By detecting the deviations in the spot

~~locations~~ locations, the distortion of the wavefront for light beam 4 can be detected.

Because this distortion is a direct result of deviations in the surface, the surface features

can be readily detected and their size and relative location can be measured.

Please amend the paragraph beginning on page 11, line 1 as follows:

Note that wavefront sensing tools operate by detecting the slope in the distortion

to the light beam wavefront. Surface features that have a very steep or no slope, such as

perfectly vertical ~~sidewalls~~ sidewalls, cannot be detected using conventional wavefront

sensing tools. Figure 4a illustrates two such features 26 and 28, commonly referred to as

piston deviations. Piston deviation feature 26 is a depression within surface 13 of

exemplary wafer 5 and piston deviation feature 28 is raised above the surface 13. Note

that sidewalls 27 of feature 26 are essentially vertical and the sidewalls 29 of feature 28

are likewise essentially vertical. Figure 4b schematically illustrates the distortion that

would be imparted onto a light beam wavefront 30 after reflecting off the surface 13 and

features 26, 28 of Figure 4a. Figure 4b illustrates two phenomena that are relevant to understanding the invention. First, note that the wavefront distortion 30 has a feature 126 corresponding to the surface feature 26 and a feature 128 corresponding to the surface feature 28. These features (which are simply distortions in the wavefront of light beam 4) have essentially zero slope at their edges. As discussed above, because wavefront sensing tools detect variations in the slope of the incoming light beam wavefront, such features would be very difficult if not impossible to detect.

Please amend the paragraph beginning on page 11, line 19 as follows:

The second phenomenon illustrated by wavefront 30 is that feature 126 has twice the amplitude of the actual surface feature 26 that was detected and feature 128 has twice the amplitude of the actual surface feature 28 that was detected. This phenomenon is explained with reference to Figures 5a and 5b. Figure 5a schematically illustrates a light beam $\underline{4}$ impinging upon a flat surface 13 and being reflected from the surface 13 to alignment mirror 6, where the beam is reflected to impinge upon wavefront sensing tool 8. Note that the wavefront is schematically illustrated as having no distortion arising from flat surface 13 (as illustrated by curve 113). By contrast, Figure 5b illustrates that the wavefront is distorted by surface feature 28, as indicated by the ~~curve~~ <u>wavefront</u> 128 <u>schematically illustrated</u> in the ~~wavefront 30 of~~ light beam [[4.]] <u>4 of Figure 5b.</u> Note, as in Figure 4b, this curve is shown with twice the amplitude as the actual feature 28. This is because the light beam 4 impinging upon the flat surface 13 of the wafer travels a distance of d_1 between the flat surface and the plane of the alignment mirror 6, whereas the light beam impinging upon the top of feature 28 travels only a (lesser) distance of d_2

between the top of the feature and the plane of the mirror. In fact, the impact of the

difference between the top of the feature and the flat surface is doubled. This is because

the light beam first travels from the light source 2 to the wafer 5 (and hence the first

distance d_1 minus d_2 is imposed) and then the light beam reflects from the wafer to the

alignment mirror (and hence the second distance d_1 minus d_2 is imposed). This

phenomenon can be advantageously exploited because it increases the sensitivity of the

wavefront sensing tool 8 (i.e. the distortions caused by a surface feature are doubled and

hence easier to detect).

Please amend the paragraph beginning on page 12, line 19 as follows:

Returning now to Figure 4c, preferred features 36 and 38 are shown; [[Note]] note

that these features have rounded sidewalls 37 and 39, respectively. As illustrates in

Figure 4d, such features impart distortion 136, 138 onto the wavefront 40 of the light

beam that has sloping features. Because the wavefront distortion has a slope, wavefront

sensing tool 8 can easily detect the features 36, 38. Note also that, as above, the

amplitude of the distortion features 136, 138 is twice that of the measured surface

features 36, 38, respectively. By scanning the wafer relative the wavefront sensing tool,

the location of surface features 36, 38, and the like, can be detected and the alignment

between them can be readily determined.

Please amend the paragraph beginning on page 13, line 6 as follows:

Figure 6 illustrates another preferred embodiment system for detecting alignment

between alignment features located on different layers of a semiconductor device. Figure

6 will be described with reference to the alignment features 12, 14 illustrated in Figure 1a. In this embodiment it is assumed, however, that one of the alignment features – say features 14 – can be detected using conventional optical alignment tools such as a high powered microscope. In Figure 6, such a conventional optical alignment feature detection system is schematically illustrated as 50. Also shown in Figure 6 is a wavefront sensing tool 8, such as described above. Tool 8 is employed to detect other features, such as features [[12]] 12, that cannot be detected using convention conventional optical tool 50. Examples of such tools could include atomic force microscopes (AFMs) and scanning electron microscopes (SEMs). Light beam 4 is shown as reflecting off of wafer [[five]] 5 (including top surface 13 and features 12, 14, although not shown in Figure 6 for clarity) as in the above-described embodiments. In this preferred embodiment, however, light beam 4 is split [[be]] by beam splitter 52, with a portion of light beam 4 being deflected to wavefront sensing tool 8 and a portion of light beam 4 passing on to optical tool 50. Beam splitter 52 can be any well-known beam splitter device.

Please amend the paragraph beginning on page 14, line 1 as follows:

Wavefront sensing tool 8 will receive the incoming light beam 4, including the wavefront distortions discussed above and will compare the received array of light spots 23 to an array for a reference surface, all as described in greater detail above. In some embodiments, wavefront sensing tool 8 will convert the detected variations in the light spots into an electrical signal or even into an image signal, which signal is then passed to computer 54. In other embodiments, wavefront sensing tool 8 merely detects [[that]] the

deviations in the light spots 23 and passes that information to computer 54, where the information is converted into image data.

Please amend the paragraph beginning on page 14, line 9 as follows:

Optical tool 50 also receives light beam 4. Tool 50 typically includes a photosensor array wherein the incoming light is detected and converted into an electrical signal. Typically, the electrical signal is converted into an image by optical tool 50, which [[is]] image is then passed to computer 54. In some embodiments, optical tool 50 merely passes the electrical signal to computer [[52]] 54 and the conversion into an image occurs in the computer. Computer 54 takes the image information from wavefront sensing tool 8 and from optical tool 50 and overlays the two images. In other embodiments, computer 54 may be integrated into the optical tool 50 or wavefront sensing tool 8. Because both tools 8 and 50 operated upon the same incoming light beam, the two images will be aligned. By overlaying the two images – with the image from wavefront sensing tool showing the location of alignment features 12 and the image from optical tool 50 showing the location of alignment features 14 – the overlay alignment between the features features, including the distance between the features, can be detected and measured. Figure 7 shows an exemplary composite image 56 showing features 112 that were detected by wavefront sensing tool [[12]] 8 overlaid with features 114 that were detected by optical tool 50.

Please amend the paragraph beginning on page 15, line 1 as follows:

In the above-described embodiment, wavefront sensing tool 8 and optical tool 50 detect the alignment features simultaneously, using the same light beam as split by beam splitter 52. Beam splitter 52 can be removed, however, in other embodiments, provided that some way of aligning the image data from the two tools is available. For instance, both optical tool 50 and wavefront sensing tool 8 might be able to detect some other feature located on wafer 13. Upon receiving image data from optical tool 50 and from wavefront sensing tool 8, computer 54 could align the images by aligning the feature that is common to both images. The common feature is referred to herein as a reference alignment mark. This type of image detection and alignment is well known in the art. One example of such a feature might be alignment features 14. These features are typically optically detectable by optical tool 50 and, because the features 14 typically also create a depression in the top surface of the ~~waver~~ wafer (see Figure 1a), they are detectable by wavefront sensing tool 8. As such, computer 52 could align image data from optical tool 50 and wavefront sensing tool 8 by aligning features 14 common to both images. In yet other embodiments, some other surface feature tool, such as an atomic force microscope, could be substituted in place of optical tool 50. Furthermore, the above teachings could be applied to yet a third alignment mark, which third alignment mark could be detected with the optical tool and an image thereof formed. In one embodiment, the third alignment mark could be formed in a layer underlying the first and second layers in which the first and second alignment marks are formed, respectively, and a composite image of the first, second, and third alignment marks could be formed, as described above.